THE GLOBAL SYSTEM OF WATER VAPOUR QUANTITY IN THE ATMOSPHERE AND ITS YEARLY ALTERATION

by

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A légköri vízgőz mennyiségének földgömbi rendszere és évi változása. A tanulmányban leírt számítási módszer alapján bemutatásra kerül a légköri vízgőz tömegének és éven belüli változásának földgömbi eloszlása. A számítások 714 állomás éghajlati adatai alapján készültek, figyelembe véve az óceáni és poláris területekről származó legújabb éghajlati átlagokat is. A Föld légköre évi átlagban 1,352 26 · 10^{16} kg tömegű vízgőzt tartalmaz, ami egyenletes eloszlásban 26,5 kg/m^2 vízmennyiséget jelent. A légköri vízgőzkészlet éven belüli változása Földünk monszunterületein a legjelentősebb, míg a legcsekélyebb éven belüli változás az egyenlítői övben, valamint a csekély párolgással rendelkező sivatagos és sarkvidéki területeken tapasztalható.

On the basis of a calculation method described in present study it was aimed to represent the within year alteration and terrestrial distribution of atmospheric water vapour contents. Calculations are based on weather data obtained from 714 stations considering at the same time recent climatological averages originating from oceanic and polar zones. The atmosphere of the Earth contains 1,352 26 · 10^{16} kg water vapour as a yearly average, which in a uniform distribution means 26.5 kg/m^2 quantity of water. The greatest alteration in atmospheric water vapour supply takes place in monsoon areas of the Earth, while the smallest changes can be experienced in the equatorial zone as well as in desert and polar territories with low evaporation rates.

1. Introduktion

Two methods can be used to explore the average water vapour quantity in the atmosphere:

1. From the average values of vapour pressure measured near the soil the water vapour contents of an air column can be calculated.

2. On the basis of measurements in the high atmosphere the mass of water vapour profile in the air column above a given point of observation can be calculated.

Latter method without doubt offers more exact results, its disadvantage is that such data is available only from relatively few places and for short periods, this way it assures only an approaching estimation of water vapour contents of the atmosphere and a superficial exploration of its structure of distribution. Even in our days for a more detailed geographical analysis the adoption of method 1 can be reccomended.

Empiric relationships are known explaining the height function z of vapour pressure e concretizing the function

$$e_z = f(e_0, z) \tag{1}$$

where e_0 means vapour pressure near the soil. Taking *average values* an approximatively satisfying exactness is assured by the formula *Süring*, according to which:

$$e_z = e_0 \cdot 10^{-z/6(1+(z/20))} \tag{2}$$

where z represents height in km-s.

If a 1 m² cross-sectional air column (length: $z=0$ to z) is divided into Δz wide sections while taking into account the average T_0 temperature at $z=0$ level (level of the soil) and the temperature profile z $T_z=T_0$ generally valid for the troposhere (according to data of normal atmosphere if z is expressed in km it equals 6,50) this way $z=z_2-z_1$ layer's average vapour pressure e and its average T temperature can be calculated on the basis of e_0 and T_0. After having calculated e and T the water vapour mass s of one unit cross-sectional and z wide air layer is given by the following, already known formula:

$$s(\mathrm{kg}\cdot\mathrm{m}^{-3}) = \frac{0{,}217e}{T}\,\Delta z \tag{3}$$

where e is expressed in units of hectopascal (mbar) while T in °Kelvin and z in meters.
The mass of the water vapour quantity of the whole air column is expressed by the following integral:

$$\underset{(\mathrm{kg}\cdot\mathrm{m}^{-3})}{S} = \int_0^z f(s)\,dz \tag{4}$$

which is considered in practical calculations on the basis of water vapour mass s summarized for layers of z. The integral (4) gives the quantity of precipitable water from an air column of one unit cross-section.

As an upper limit of integration in our calculations the heighths of tropopause referring to normal atmosphere was considered, i. e. $z=11$ km value was uniformally accepted for the whole surface of the Earth. Because the height of the points of observation is different and not uniformally 11 km but 11—h km high, so the water vapour mass of one unit cross-sectional air column has to be considered in 11—h height above sea level meaning h expressed in kilometers.

Generally, it can be stated, that

$$S = F_1(e_0, T_0, h) \tag{5}$$

and

$$S(\mathrm{kg}\cdot\mathrm{m}^{-2}) = \alpha\cdot e_0 \tag{6}$$

where

$$\alpha = F_2(T_0, h). \tag{7}$$

A graphical demonstration of empirically defined values of function (7) is represented in *Fig. 1*.

To determine the global distribution of water vapor in the atmosphere the monthly mean e_0 and T_0 values from 714 stations were considered. These average values refer mostly to the period between 1931 and 1960, though from polar and oceanic territories 5—10 year old normal values were necessarily used in order to obtain a net of sufficient density.

From the averages of monthly water vapour quantities the yearly mean water quantity was determined as well $S=S_{max}-S_{min}$ difference characterising the yearly circulat ion of water vapour, where S_{max} represents the maximal value of monthly average water vapour content and S_{min} its minimal value.

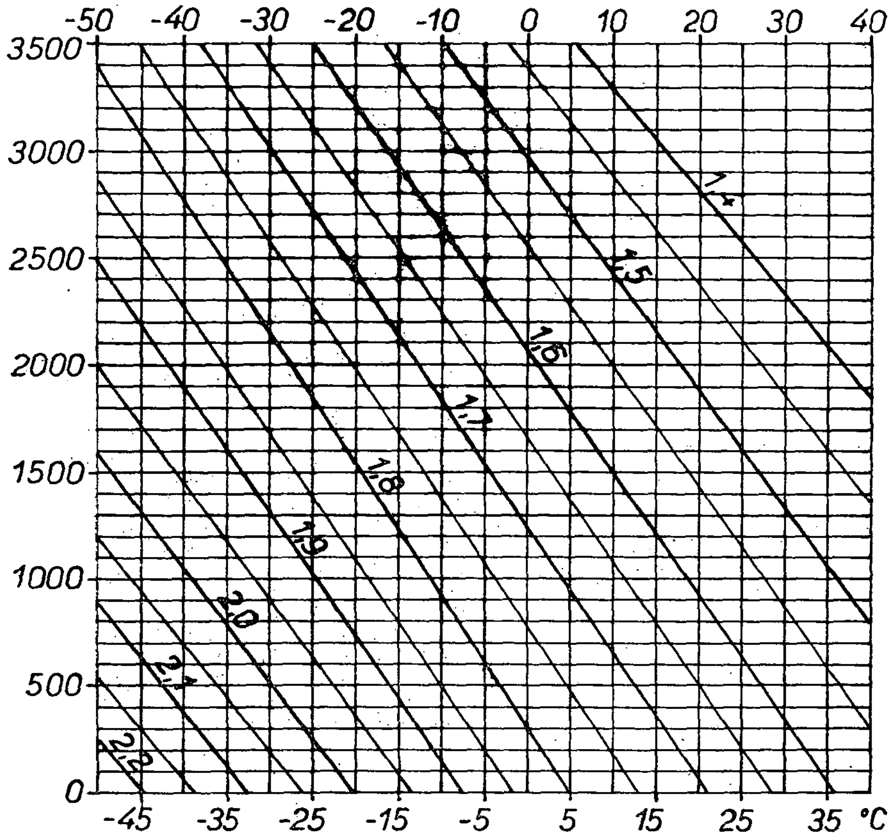

Fig. 1. Aid to determine atmospheric water vapour contents

2. Terrestrial distribution of water vapour contents of the atmosphere

The terrestrial system of water vapour contents in the atmosphere can be most concisely characterised by its yearly average value *(Fig. 2.)*

A temperature zonal system is at once conspicuous. The overwhelming part of the torrid zone is characterised by a water vapour contents above 45 kg/m^2, and on the most water vaporous territories between 50—55 kg/m^2 can be found (Western part of equatorial zone of the Pacific, Eastern part of the Indian Ocean around the Equator, Pacific coast of Columbia).

Lowest water vapour contents due to constantly low temperatures can be found in polar territories where its yearly average value does not reach 2 kg/m^2, moreover above the inner plateau of the Antarctic, which lies in a great height, is even less than 1 kg/m^2. Characteristic water vapour-arm territories emerged at low and middle geographical latitudes in inner and high territories of great continents as well (in Asia the highland of Tibet, the Iran basin, in Africa the central territories of the Sahara, in North-America the basins between the Coastal Mountains and the Rocky Moun-

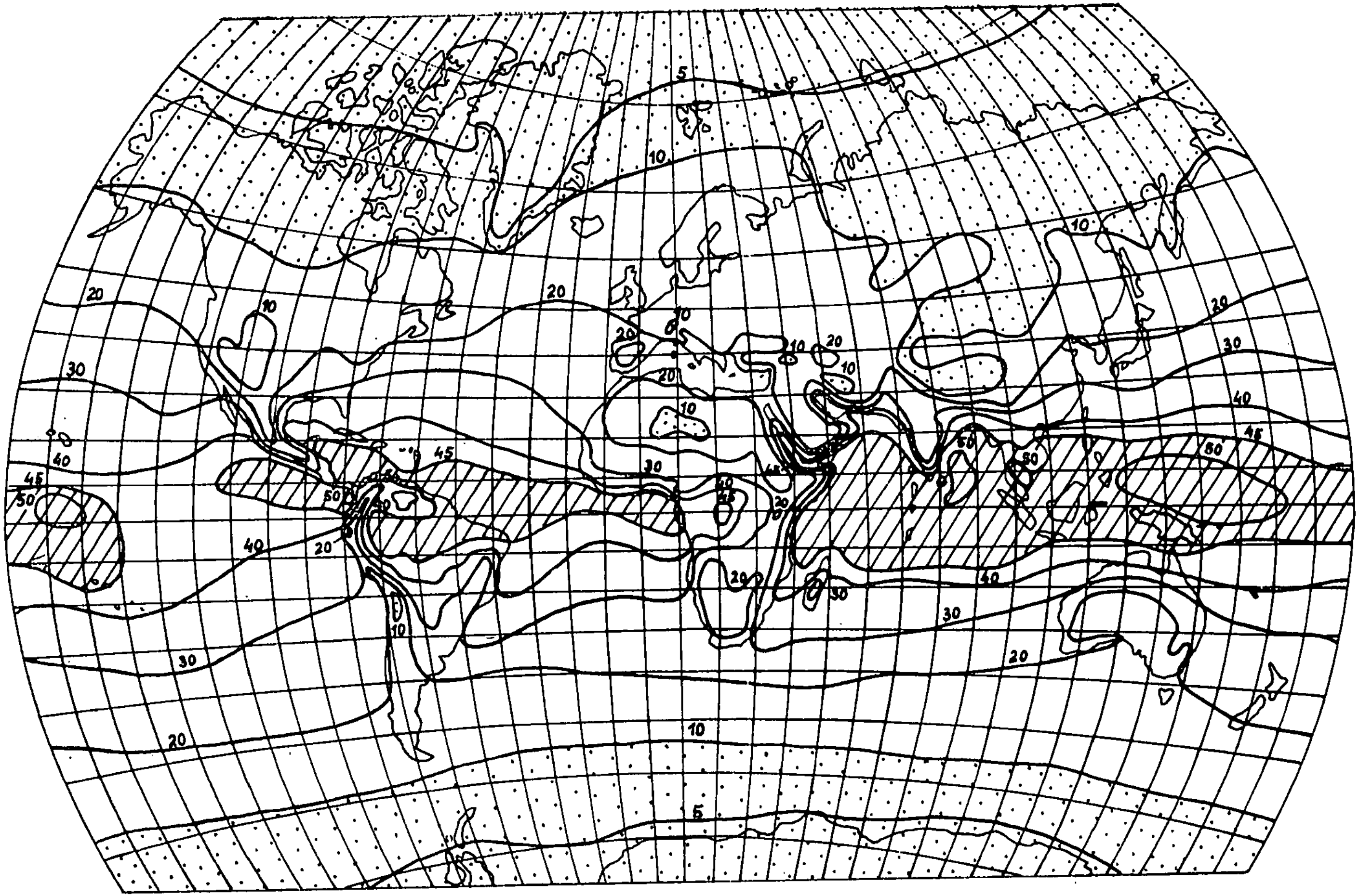

Fig. 2. Terrestrial distribution of yearly average of atmospheric water vapour contents (kg/m²)

tains (the yearly average water vapour contents value remains below 10 kg/m². On the basis of this data the water vapour contents of the different terrestrial zones can be calculated and by summing up the obtained results the mass of the total quantity of water vapour in the atmosphere can be deducted. This data is illustrated in *Table 1.*

Table 1

Zonal Distribution of Atmospheric Water Vapour (S)

	S(10^{14} kg)
90°—80° N	0,160
80°—70°	0,693
70°—60°	1,730
60°—50°	3,221
50°—40°	5,316
40°—30°	8,230
30°—20°	12,203
20°—10°	16,727
10°— 0°	19,780
0°—10° S	19,585
10°—20°	16,452
20°—30°	12,477
30°—40°	8,838
40°—50°	5,617
50°—60°	2,879
60°—70°	1,049
70°—80°	0,247
80°—90°	0,022
Earth	135,226

The mass of water vapour contents in our atmosphere is $135{,}226 \cdot 10^{14}$ kg in one year, which means 26,5 kg/m² water quantity in a uniform distribution. 50% of this water vapour quantity can be found in the torrid zone limited by 19° N and 18° S longitudinal degrees, and only its 10% can be found in the atmosphere between 90° N—47° N and 90° S—44° S degrees.

3. Within year modifications of water vapour contents of the atmosphere

The numerical value characterising the yearly circulation of water vapour is given by the difference of maximal and minimal monthly averages. The modification of atmospherical water vapour contents within a year is caused by two factors. A decisive role is played by the yearly alteration of temperature, since if the temperature rises, the air's capability to accomodate vapour increases too. In some of the sections the advection of water vapour appears to be a significant factor. This means transportation of water vapour from faraway territories which gives as a result a greater alteration in water vapour contents within a year than explained with the annual modification of temperature. In territories where water in the covering layer of the soil is limited there is no, or if at all, a reduced water supply ensuring evaporation, the yearly alteration of water vapour contents becomes less as justified by the rate of temperature change.

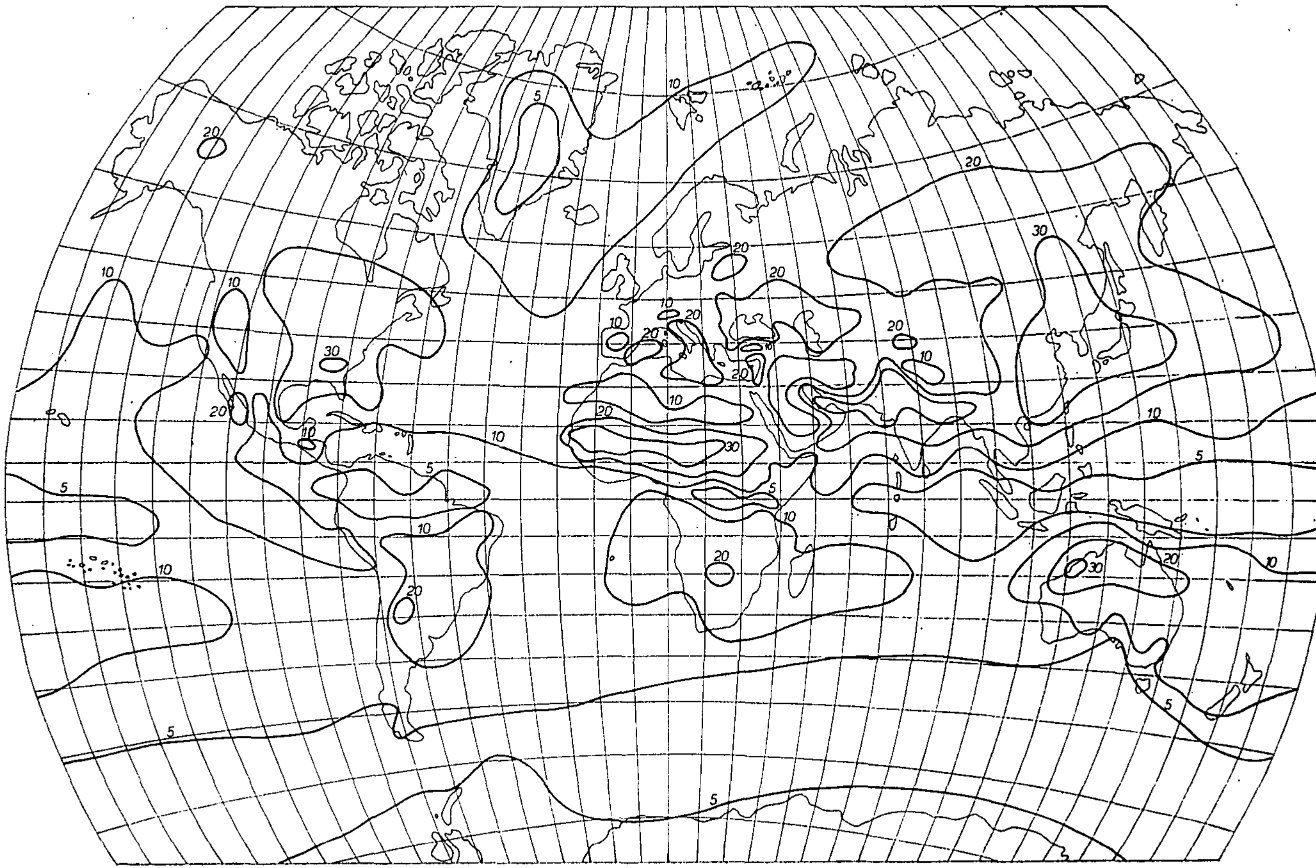

Fig. 3. Yearly terrestrial distribution of atmospheric water vapour content changes (kg/m²)

A survey of the global system of this process can be observed in *Fig. 3.* denominating $S = S_{max} - S_{min}$ values. The within year alteration of water vapour contents appears to be the greatest (30 kg/m^2) in monsoon territories of East and South Asia, Central Africa, Australia and North America where the water advection activity is quite high during the summer months. The smallest within year alteration (5 kg/m^2) was found in the equatorial zone with constant temperature, in the dry deserts and in the polar zones with low evaporation (inner areas of Antarctic and Greenland).